DOCUMENT RESUME

ED 097 900 IR 001 268

AUTHOR	Baker, James D.
TITLE	Quantitative Modeling of Human Performance in Information Systems. Technical Research Note 232.
INSTITUTION	Army Behavioral Science Research Labs., Arlington, Va.
REPORT NO	BESRL-TRN-232
PUB DATE	Jun 74
NOTE	30p.
JOURNAL CIT	Ergonomics; v13 n6 p645-64 1970
EDRS PRICE	MF-$0.75 HC-$1.85 PLUS POSTAGE
DESCRIPTORS	Conceptual Schemes; Decision Making; Evaluation Methods; Information Processing; *Information Systems; *Man Machine Systems; *Measurement; Teaching Procedures
IDENTIFIERS	Automated Systems; Command Information Processing Systems; Quantitative Model; System Evaluation; System Performance

ABSTRACT

A general information system model was developed which focuses on man and considers the computer only as a tool. The ultimate objective is to produce a simulator which will yield measures of system performance under different mixes of equipment, personnel, and procedures. The model is structured around three basic dimensions: (1) data flow and processing, (2) task analysis, and (3) outside sources of variation in the system. Five basic and critical functional areas represented in the model are screening incoming messages, transforming messages to computer format, inputting messages, assimilating data displayed, and deciding on courses of action based on information obtained. The impact of human performance in the model is reflected in measures of system performance (throughness of information and responsiveness to the user need) and quality of information (completeness and accuracy). The model at present stage is a tested implement for human factors experimentation on the Army's information processing systems. The approach provides integrative coverage of all aspects and relationships of the man-machine interface and ties them to accept system performance measures. (Author)

ED 097900

Technical Research Note 232

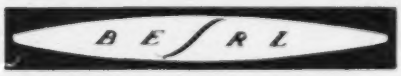
AD 746 096

QUANTITATIVE MODELING OF HUMAN PERFORMANCE IN INFORMATION SYSTEMS

James D. Baker

SUPPORT SYSTEMS RESEARCH DIVISION

U.S. DEPARTMENT OF HEALTH
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION
THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY



U. S. Army

Behavior and Systems Research Laboratory

June 1972

Approved for public release; distribution unlimited.

IR 001 968

BEHAVIOR AND SYSTEMS RESEARCH LABORATORY

An activity of the Chief, Research and Development

J. E. UHLANER
Director

Reprinted from

ERGONOMICS, 1970
Vol. 13, No. 6, 645-664

NOTICES

DISTRIBUTION: Primary distribution of this report has been made by BESRL. Please address correspondence concerning distribution of reports to: U. S. Army Behavior and Systems Research Laboratory, Attn: RDMR-BLZ, 1300 Wilson Boulevard, Arlington, Virginia 22209.

FINAL DISPOSITION: This report may be destroyed when it is no longer needed. Please do not return it to the Behavior and Systems Research Laboratory.

NOTE: The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

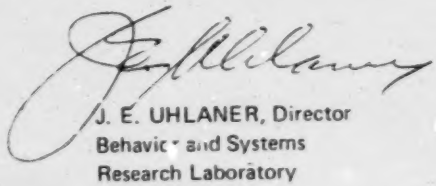
BESRL Technical Research Reports and Technical Research Notes are intended for sponsors of R&D tasks and other research and military agencies. Any findings ready for implementation at the time of publication are presented in the latter part of the Brief. Upon completion of a major phase of the task, formal recommendations for official action normally are conveyed to appropriate military agencies by briefing or Disposition Form.

FOREWORD

Technological advancements have led to increased speed, mobility, and power of military operations. To permit commanders to make tactical decisions consistent with rapid change and succession of events, information on military operations must be processed and used more effectively than ever before. To meet this need, the Army is developing automated systems for receipt, processing, storage, retrieval, and display of different types and vast amounts of military data. There is a concomitant requirement for research to determine how human abilities can be utilized to enable command information processing systems to function with maximum effectiveness.

BESRL's manned system research in this area is directed toward the enhancement of human performance and facilitation of man-machine interaction in relation to total system effectiveness. It involves experimentation with various configurations of system components, considering interactions and tradeoffs. The end products--immediate or ultimate--are scientific findings on human capabilities under varying conditions within the system. The findings have implications for systems design, development, and operational use. The present publication describes conceptual efforts toward the ultimate development of a quantitative model as a tool for measuring and predicting the performance of military information systems when personnel, procedures, and equipment are varied.

The entire research effort is responsive to requirements of Project 2Q062106A723 "Human Performance in Military Systems," FY 1971 Work Program, and to special requirements of the Assistant Chief of Staff for Force Development, the Assistant Chief of Staff for Intelligence, the U. S. Army Combat Developments Command, and the U. S. Army Computer Systems Command.



J. E. UHLANER, Director
Behavior and Systems
Research Laboratory

QUANTITATIVE MODELING OF HUMAN PERFORMANCE IN INFORMATION SYSTEMS

BRIEF

Requirement:

To develop conceptually a general purpose model of man-computer interactions in a military information processing system that will yield measures of systems performance under different mixes of personnel, equipment, and procedures.

Salient Characteristics of the Model:

1. Focus is on man as operator and user and on the computer as tool.
2. Model is structured around three basic dimensions: 1) data flow and processing, 2) task analysis, and 3) outside sources of variation in the system.
3. Functional areas represented in the model are screening incoming messages, transforming messages to computer format, and inputting messages.
4. In the model, the impact of human performance (screening, transforming, and inputting) is reflected in measures of systems performance (thoroughness of information and responsiveness to user need) and quality of information (completeness and accuracy).

Utilization of Conceptual Model:

1. Provides framework for measuring the impact of human performance on system performance.
2. Task analysis yields exact description of each person's job and thus provides a basis for comparing results across experiments.
3. Can provide findings on human performance useful in design or modification of systems software and hardware.
4. Modular design permits introducing experimental data or theoretical values in the system simulation and assessing the impact on one or all of the model dimensions.
5. Aids in setting priorities for research on specific human factors problems in Army information processing systems on the basis of cost effectiveness and potential payoff.

Model at present stage is a tested implement for human factors experimentation on Army's information processing systems. The approach provides integrative coverage of all aspects and relationships of the man-machine interface and ties them to accepted system performance measures.

ERGONOMICS, 1970, VOL. 13, NO. 6, 645–664

Quantitative Modelling of Human Performance in Information Systems*

By J. D. BAKER

Behavior and Systems Research Laboratory,
1320 Wilson Boulevard, Arlington, Virginia 22209, U.S.A.

This paper summarizes an approach toward developing a general information system model which focuses on man and considers the computer only as a tool. The ultimate objective is to produce a simulator which will yield measures of system performance under different mixes of equipment, personnel and procedures. In structuring the framework for this model, the assumption was made that men have five basic and critical operations to perform in an information system: screen, transform, input, assimilate and decide. These operations, or functional areas, are interrelated along three dimensions: (1) a data flow and processing dimension; (2) a task analysis dimension for each event in the data flow sequence; and (3) a source of variation dimension, such as level of training. The model approach described has several major points of payoff. Among the immediate benefit is the potential for using the model to quantify human performance by employing system measures and the value of the model as a tested, usable tool for developing test and evaluation plans which will provide human factors data as part of the information system design verification checkout.

1. Introduction

For the past two decades a considerable amount of effort has been expended in the development of military command and control systems, management information systems, and the application of information system technology to education and training. (See Bauer 1963, Shuford 1965, Baker 1968 and the special issue of *Educational Technology*, June, 1969.) In nearly all instances these efforts have involved quantification of man-computer performance in order to determine how well a system or system concept satisfied user requirements. From these efforts a number of techniques and methodologies have evolved for measuring and evaluating information systems in diverse situations (see Spiegel and Walker 1965). This development is a useful and worthy endeavour. The capability to predict information system performance in varying situations is, however, a much more profitable and desirable goal.

At present, one of the more successful (although expensive) methods of predicting system performance is to configure a prototype system and test it in the context for which it was designed. In this manner representative problem areas are probed, and the findings used as feedback to continue testing and development effort. A prototype system setting provides a rich, but difficult, environment within which to quantify human performance in information systems. One need work only a brief time in an operational

---

* The contents of this paper were presented at the Fourth International Congress on Ergonomics, Strasbourg, France, 6th–10th July 1970 as the opening address of the Machine-Aided Processing of Information Session. The opinions expressed are solely those of the author and do not necessarily reflect official Department of the Army policy. Reproduction in whole or in part is permitted for any purpose of the United States Government. The author wishes to acknowledge the many contributions made by his friend and colleague, Douglas J. Mace, during the development of this paper.

environment utilizing a pilot configuration of a system before one is struck by the fact that a more economical way to achieve considerable predictive power is to develop a model for simulating different information system configurations in diverse situations.

The term model, as Kac (1969) has noted, is used (or misused) in many ways. In the present context the term *model* refers to an analogue, or representation of reality. *Simulation* refers to the construction and use of the model for purposes of prediction through testing various design configurations. In the colourful words of Hamilton and Nance (1969): 'One "wiggles" each part in order to see what will happen when all the parts are taken into account.'

Inroads have been made toward the development of information system models which simulate primarily hardware and/or software configurations (Estrin and Kleinrack 1968, Blunt 1966, 1965 and Fine and McIsaac 1964). But with few exceptions (notably the work of Carbonell 1969 and the recent book by Siegel and Wolf 1969), there has been little progress in the realm of modelling and simulating the man portion of a man-computer information system.

In this regard in 1967 Turoff (as reported by Nickerson 1969) expressed the expectation that psychology would contribute greatly to the construction of meaningful immediate access, or interactive, man–computer information systems. Nickerson goes on to say that little has occurred in the meantime that would lead one to believe that the evolution of these systems has been greatly influenced by psychology. One reason for this lack of impact is the absence of a suitable model which concerns itself with the psychology of man–computer interactions. He suggests one approach to developing such a model: 'By focusing on the man, and treating the computer as a tool that he uses, one increases his chances of developing models that are not system specific and that may be valid for a significant period of time in spite of the rapidity of the technical developments in the computer field.' I strongly concur with Nickerson's proposal since, independently, I have been working toward this goal for the past three years.

In this presentation, I shall attempt to summarize my efforts to date toward developing a general information system model which focuses on man and considers the computer only as a tool to be used in their mutual endeavours. It is not my intention to present this model as a final developed simulator, but rather as a base for the continued development of such a performance measurement and predictive tool. I have taken a modular approach which permits other researchers to contribute by 'plugging into' the model their findings with regard to the quantitative aspects of human performance which relate to the functional areas to be described. The ultimate objective of this endeavour is to develop a general purpose model of man–computer interactions which will yield measures of system performance under different mixes of equipment, personnel, and procedures

2. Overview of the Model

One of the most interesting by-products from any research effort is the development of techniques, methodologies, and concepts which may have more generality than the direct products of the effort itself. Ringel (1966), in laying out a programme of research aimed at resolving some of the anticipated

man–machine problems in the military information system area, delineated at least five critical functional areas requiring experimental attention (see Figure 1). In his words:

> 'Looking at the system as a whole, there appears to be five critical operations that man and equipment will have to perform: (1) *screen* incoming data for pertinence, credibility, impact, priority and routing; (2) *transform* the raw data for input into storage devices; (3) *input* the transformed data into storage devices for subsequent computation and display; (4) *assimilate* data displayed; (5) *decide* on courses of action based on information displayed and information from other sources.'

Ringel's macro-structure appears to be generally applicable to information systems, going beyond the military command and control information systems upon which he was focusing. The structure shown in Figure 1, therefore, will serve as the general framework for my presentation. The emphasis is on the 'measures of the front-end of the system', . . . the screen, transform, and input areas.

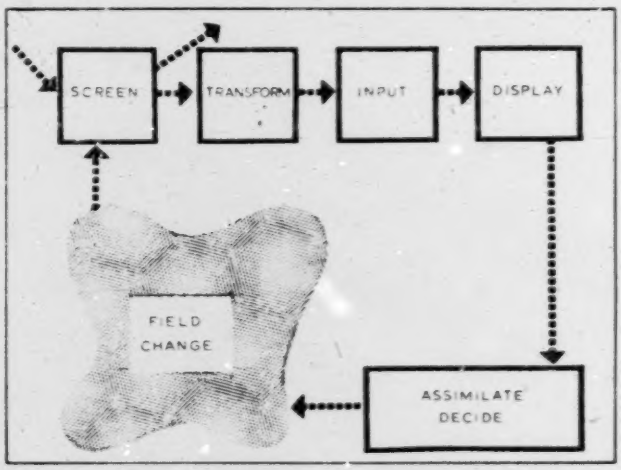


Figure 1. General framework showing critical human performance functional areas for information systems. (Taken from Ringel 1966.)

Problems of format and format selection quite often occur in information systems as an adjunct to the screen and transform functions. The trend in information systems is to allow the user on-line communication with the computer and intervention in computer operations. Accompanying this trend has been the development of rigidly defined user/computer languages. These languages are, and within the current state-of-the-art must be, most precise. They are intolerant of errors. Errors, even if slight, usually result in the computer's rejecting a message.

This typical inflexibility of computerized information systems accounts, in part, for problems in the first two human performance areas—screen and transform. Screening is required because most systems are not capable of accepting every iota of data. Redundant, irrelevant, and unimportant data

are filtered out because the software is typically unprepared to respond appropriately. Transformation generally involves formatting and translating. Formatting is necessary because of input hardware restrictions and the fact that computers read character positions or fields, not words or sentences. A further restriction is that software frequently assigns differential meanings to positions and fields. Thus, a '2' in column one is not necessarily equal to a '2' in column ten. This restriction leads to translation requirements. Because the user/computer language typically requires exact syntactic structure, abbreviations, and terminology in order for the message to be accepted by the computer, the typical free text that characterizes military messages in non-automated systems must be transformed into a rigidly defined format before the user can interact with the computer.

With this general framework in mind, let us now turn to the model itself. The model has been developed along three basic dimensions which are reflected in Figure 2. The first, that of data flow and the processing it requires, constitutes one dimension of importance. Hence, it is critical to 'flow chart' the sequence of events or operations that constitute the logic of the system under examination. A basic consideration in identifying each event is that the sequence must be structured in terms of an observable start and stop point before it can be quantified in terms of time measures.

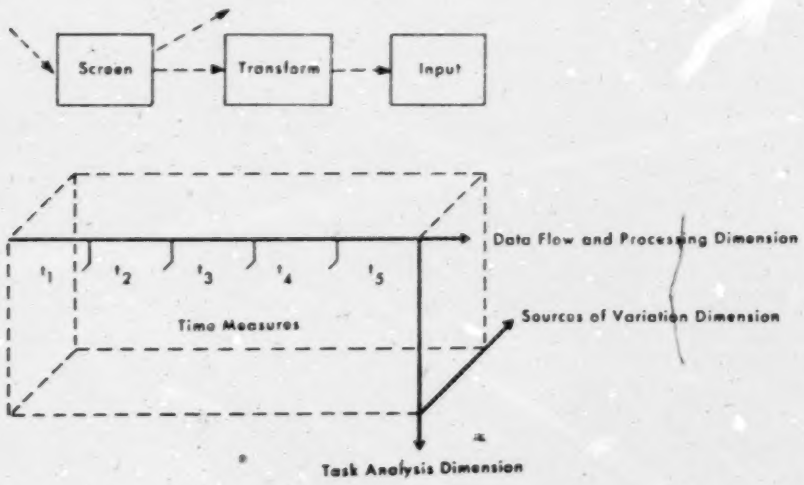


Figure 2. Basic dimensions of the model.

For the second dimension, task analysis, each event in the data flow sequence is examined with respect to the task-equipment interactions that constitutes that portion of the operator's job. An example would be to do a task analysis of the input operator's activities during time interval t_5. Essentially, a task analysis consists of the enumeration of the discriminations, decisions, and action responses which are necessary and sufficient to operate each component of the system.

The third dimension refers to outside sources of variation which are normally considered external to the man–computer system, for example, the impact on system performance when level of training is varied, or group structure, or operations over extended periods of time.

3. Data Flow and Processing Dimension

How do we go about applying these concepts to a specific information system? We begin with the assumption that a conceptual configuration of our information system has been spelled-out in a set of design specifications, and we wish to examine and relate the effects of a variety of human performance measures on this system. To establish the horizontal dimension which directs the basic flow of data, we use a time-line analysis approach. A time-line analysis is essentially an analytic technique which provides a time base for the functional and temporal relationships among tasks.

Figure 3 illustrates this procedure in a military information system. The data flow, observable events, and the time interval aspects of the system have been mapped out in terms of their relationship to the human performance functional areas of screen, transform, and input. The input data to be acted upon have been delineated, for purposes of illustration, as military communications arriving at the message branch of an operations centre by means of voice or teletype (TWX) channels. Because our basic concern is with the human functions associated with the 'newly introduced' automation of the operation centre activities, we have initiated our user performance measure at the event 'IN-basket,' the first point of contact between the automated system and the centre operations.

In our illustration the first time interval (t_1) begins with the insertion of a message into the action officer's IN-basket and ends when he pulls it out of the basket to begin processing it. If we were simulating this flow of events, the start time for t_1 would begin with the time prescribed by our simulation message insertion script. The end time, however, is free to vary; therefore this measure would require an observer to record the interval manually. Interval t_5, on the other hand, could be machine recorded if the simulation were run in conjuction with a computer. The point being made here is that even though this is a man–computer system a comprehensive time base for data throughput cannot always be automatically acquired. Rather, the summation of manually recorded, as well as computer recorded, measures are sometimes required in order to determine the time involved in throughputting system data when human information processing is involved. For example, in the illustrative system (Figure 3), it takes t_k (an inserted constant for message transcription time) plus the manually measured time intervals t_1, t_2, t_3, and t_4, (as well as the computer recorded time interval t_5) to throughput data from message receipt to arrival in the data base when the human information processing functional areas of screen, transform and input are involved.

Interval t_1 serves to illustrate another advantage accrued in performing a time-line analysis. Considered alone, t_1 provides data on queue length and time per item in queue; thereby pinpointing nodes which are in effect bottlenecks in information throughput. When such nodes are identified as being

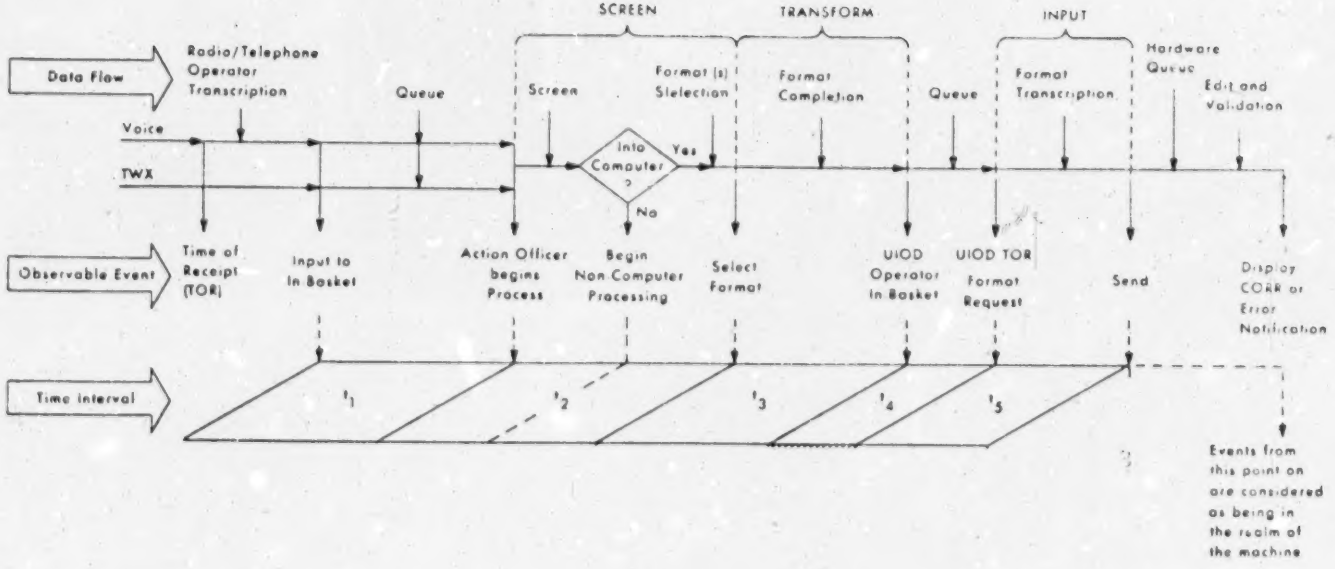


Figure 3. Data flow, observable events, and time interval aspects of an illustrative military information system as they relate to the human performance functional areas of screen, transform and input.

associated with a human information processing task, meaningful research may be undertaken in an attempt to optimize system performance by uncovering those factors which will improve human performance. For example, one could measure the impact on a queue of introducing two action officers at node t_1 during simulation to determine if it resulted in overall improvement in system data throughput.

Setting up the time-line dimension is not without certain difficulties. Time interval t_2, screen and format selection, is a case in point. This time interval is admittedly a weak, but important measure. Its weakness lies in the fact that it is difficult if not impossible to separate the screen task from the format selection task since the two may overlap and the end of one and the beginning of the other task is not always observable. At the time the action officer picks the message out of the IN-basket, he presumably scans it to determine if the information is applicable to the system's data base, or, in the event that it is a request for information, whether the system can provide it. The outcome of the processing by this individual, will be based in part upon his determination as to whether a format exists to handle the data contained in the message. To this extent he has engaged in format selection at the same time he is screening it. Measure t_2 is further complicated by the fact that complex messages may require the selection of several different formats in order to accomodate all the data included in a single incoming message.

Hence, t_2 measurement starts when the action officer selects a message and ends when he picks-out a format worksheet and begins to complete it. But ' clean ' format selection time can be obtained only for messages requiring a single format. For multiple format messages, the appropriate measure is t_2 through t_3, the combined selection and completion tasks.

Shifting to a molar or macroscopic level to describe certain man–machine interactions is frequently necessary in working through this time-line dimension. For example, a related situation has been reported by Scherr (1965). In his study no fine grain partitioning of activities was attempted at the input function which would distinguish the time the user spends inputting data and the time he spends thinking. ' Thinking time ' was necessarily equated with the console part of the interaction in Scherr's analysis. From these, and other examples, it becomes evident that it is sometimes impossible to deal with these processes at any level other than that of a ' black box ' operation.

More could be said about the specifics depicted in Figure 3, but my aim has been to describe only the general considerations involved in structuring this dimension of the model and to relate human performance to the system's data flow. To review, modelling begins with a time-line analysis which provides a time base for the functional relationships among the tasks. A comprehensive picture of the processing involved in throughputting the data is required in order to insure that no critical man–machine interaction nodes are overlooked. A complete data flow representation is necessary if one intends to quantify human performance by employing system measures. Even in computer-based systems, some manual recording is required since processing can occur in front of, parallel to or outside the direct man–machine interfaces. This time-line dimension helps to dramatise queue nodes where high payoff human information processing research could be conducted. Necessity may require us to ' shift gears and go to a molar level ' in describing certain tasks.

4. Task Analysis Dimension

Given the horizontal dimension (data flow, observable events and the time interval aspects of the system) we can undertake to develop the vertical dimension for each observable event or task. Whereas time-line analysis was the tool for developing the horizontal dimension, task analysis is the technique which lends itself best to developing the vertical.

Task analysis, according to Miller (1962), is a process which provides data about human functions: data useful in determining the characteristics of job aids, training programmes, and the assessment of performance of the system and its components. The overall task analysis for a given system provides specific statements of all the interactions of man with machine and of man with the system environment.

Human tasks must be described within the context of the major categories of functions associated with the expected operation of the system. There are, of course, various levels at which the description of the total operations of a man-computer system may be stated. Miller (1962) suggests that before a task analysis is undertaken a subsytem level in the system description must be reached at which the individuals involved are performing some distinguishable portion of the system's purposes.

The horizontal dimension consisting of data flow, observable events, and time interval aspects of the system can be used as a vehicle for arriving at this level. Figure 4 shows how the various levels of operational description are applied in the model paradigm. At the grossest level, level 1, we distinguish the broad catagories of functions necessary to insure that the system will fulfill the purposes for which it was designed. These are the human functions of screen, transform, and input, and the parallel (but not shown) machine functions of shunt, pre-process, queue, digital code, and edit and validate that taken together constitute the data flow. So far, the functions described apply to almost any information system regardless of purpose. The next level of specificity brings us to the particular activities associated with the military information system chosen as our example, i.e. action officer selects military communication from message IN-basket. If we now consider a particular function such as completion of a format requesting the status of a friendly unit, it is evident that the progression has been from the transform function level (level 1), to the format completion level (level 2), and on to level 3 where the specifics of transforming a particular class of message to a specific format may be delineated. It is at this level that a detailed task analysis may be undertaken.

Many techniques exist for implementing the task analysis (Lyman 1960). For purposes of illustration, an extremely simplified example is given of one such technique, taking the task group as the basic unit. A task group is the required complete sequence of responses by an operator, performed as a result of an external stimulus, or indicator action. This indicator action may be as simple as placing a transcribed message in the IN-basket or as complex as the generation of an attention device on the display surface. The indicator action is always initiated by a source external to the operator position being described. Responses to serial stimuli resulting from an individual's own actions are called feedback to distinguish them from indicator actions described above. In any event, a task group always begins with an indicator action and continues to an end event.

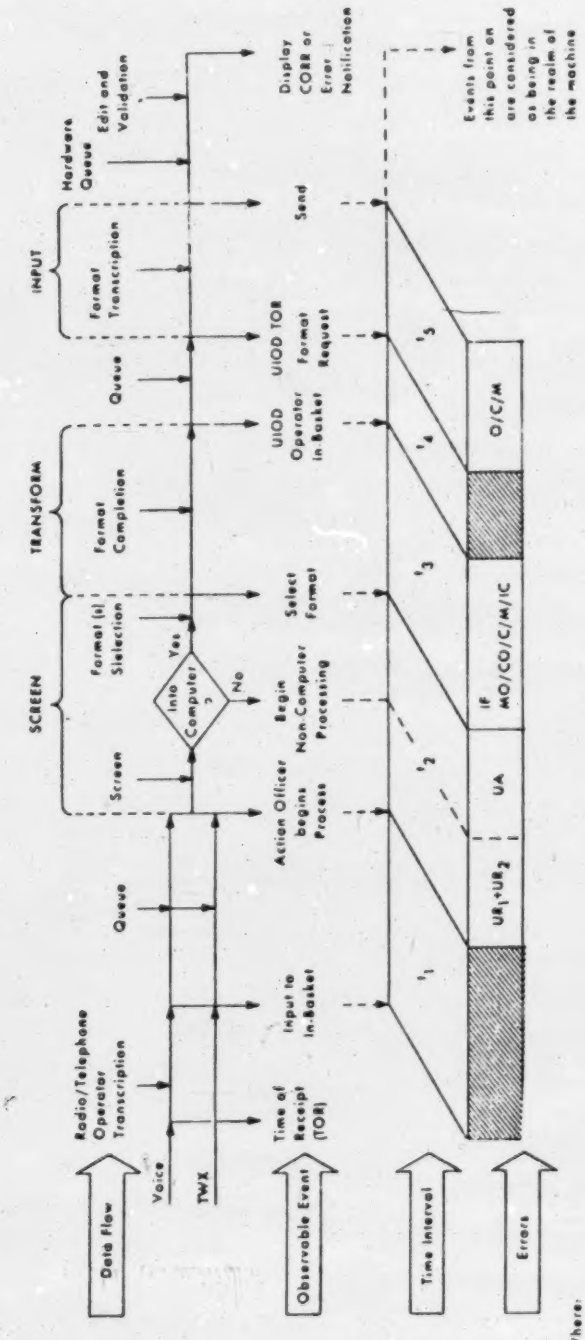


Figure 4. Diagram of information system showing data flow time intervals and the critical errors which can occur at these intervals.

A truncated worksheet for analyzing the action officer's task concerned with completing a specific format used in our illustrative system is shown in Figure 5. The worksheet selected is based upon a particular approach used by Warburton, *et al.* (1960). The columns in Figure 5 have meaning as follows:

Item. Number used to designate an entry.

Response Required. Response required in terms of product or result rather than method.

Action. Specific act or acts which must be taken to implement the response required.

Who. The person taking the action.

Feedback. State resulting from an action which indicates the adequacy with which the response required has been performed; it may serve as a stimulus for serial actions.

Recipient. Person or workplace component to whom the person designated in the *who* column transmits information.

Remarks. Minor elaboration of content of item or cross reference.

Fall-out from the task analysis effort results in at least two products important to this model. First, subsets of time intervals concerned with each response required by each task can be identified to determine which aspects of the task are contributing most to our horizontal dimension time interval measures (t_1, t_2, etc.). Those task response times which seem likely to become inflated are prime candidates for experimental attack when one sets out to improve man's performance in order to optimize system performance. As a second

TASK ANALYSIS

VI. Format Completion

INDICATOR: Format selected for message. SOURCE: SOP and Handbooks.

Item	Response Required	Action	Who	Feedback	Recipient	Remarks
1.	Our action officer has just screened a message taken from the IN-basket and selected a Unit Status Query message to complete					
2.	Select precedence for message	Place an " I " for immediate in precedence field.	AO			
3.	Need hardcopy for own files	Place " Y " in hardcopy field of worksheet	AO			
.						
.						
.						
Nth	Correct errors uncovered by computer	Determine if error was a mandatory field ommission	AO	Error Display on CRT	UIOD operator	Correct Worksheet and replace in UIOD operators IN-basket
.						
.						
.						
N+1	Action officer returns to screen process					

Figure 5. Truncated task analysis worksheet describing responses required of the individual completing a specific format in our illustrative system. (Based upon an approach used by Warburton *et al.* 1960.)

valuable product, the task analysis helps to identify the sources and types of critical human errors that can be introduced into the system.

In Figure 4, a number of critical errors associated with the illustrative system are shown in conjunction with the data flow time interval at which they could occur. Such a list is a product of the task analysis. In our illustrative system, a 'mandatory omission' refers to the omission of certain information which causes the system to reject the message when the user attempts to input it. The result could be that the data base must wait for, or could be deprived of, the final datum required to resolve an important and puzzling problem. For example, our illustrative task analysis of time interval t_3, the Nth item (Figure 5) noted that a mandatory field omission could occur during format completion.

More could be said about the specific errors shown in Figure 4, but these are meaningful primarily in the context of the illustrative system. Each system could have its own rigidly defined, human introduced errors which should surface in the process of conducting the task analyses for that sytem. (Hopefully, a taxonomy of general human information processing tasks will evolve from the large amount of ergonomics and human factors research currently being conducted, to which specific types of errors may be related.)

In summary, the intention of this segment of the discussion has been primarily, to show how the data flow and processing dimension depicted in Figures 2 and 3 can be used as a jumping-off point for working down to the sub-system level at which a detailed task analysis can be undertaken. Many techniques exist for conducting task analysis, but basically they boil down to an enumeration of the discriminations, decisions, and action responses which are necessary and sufficient to operate each component of the system. The task analysis can serve as a source of a number of rich human factors discoveries . . . among them the identification of critical subsets of human performance time data which are operating to interrupt system data flow at designated intervals in the system. Also, the development of this dimension is responsible for the enumeration of errors which may impact on the total system performance.

5. Sources of Variation Dimension

It was noted earlier that human performance in an information system may be influenced by sources of variation which are normally considered external to the man-computer system. Among the sources of variation particular to the military system illustrated (Figure 6) are staff elements and echelons. But many general things (e.g., level of training) impact on a man's job in an information system. To define the term job in an information system we need to return to our preceding discussion on the task analysis dimension of the model. It was noted that a task analysis essentially consists of a delineation of the response required at each step in a task sequence. The cluster that constitutes task sequence is a task group. The cluster of task groups for a given person in the system constitutes his job.

What are some of the factors which affect the perfomance of a job in an information system? Two factors which immediately come to mind are training and how well the equipment has been engineered. Training adapts a person to a job: human engineering adapts the job to the person. Individuals vary in intellectual capacity, also in the capacity for adjusting to new situations

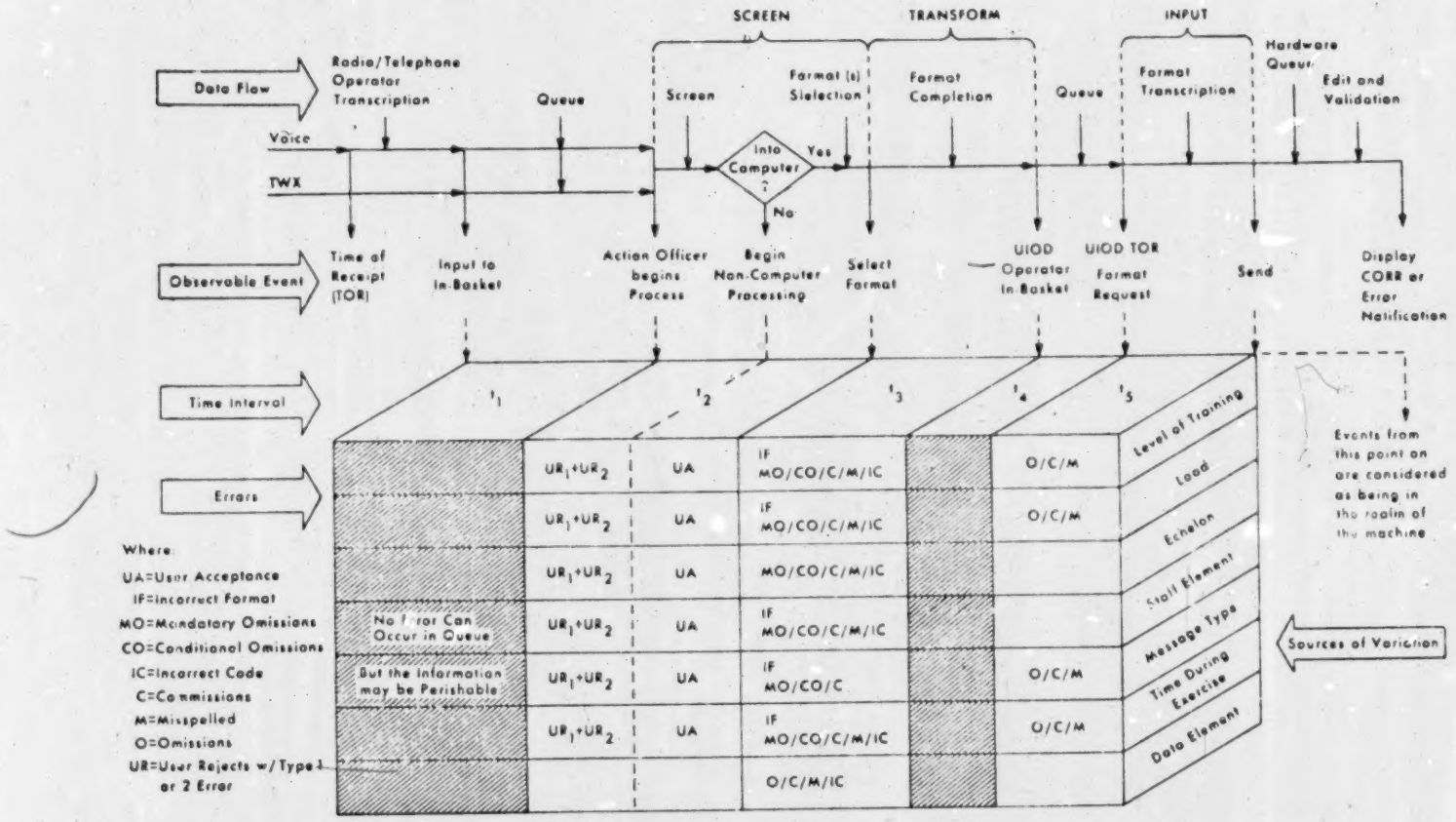


Figure 6. Sources of variation normally considered external to the system as they relate to data flow time intervals and critical errors for our illustrative system.

and in physiological capacities for perception. The system may not function optimally because a key individual does not have the aptitude required for the performance of the job. He may not have the capacity to remember relevant facts or to integrate facts into decisions. Lack of aptitude is, by definition, irremediable. However, if an individual has the aptitude required for a job, he can be trained in the skills and knowledges necessary for adequate performance. Training is used broadly to include formal courses, on-the-job training, and relevant experience. The value of appropriate selection techniques, therefore, cannot be minimized.

A man may be unable to do a task because he is too tired or too sick, although he has the necessary aptitude and training. So, the system may perform less than optimally because a key individual is temporarily in a physical state which precludes adequate performance. This situation was reflected in our illustrative system by the inclusion of 'Time During Exercise' as a variable external to the system (see Figure 6).

Assume that an individual is assigned to a humanly possible job, that he has the necessary aptitude and training, and that he is in reasonably good physical condition. In other words, he is able to do his job properly; whether, in fact, he will do it properly depends on his motivation. The system may operate sub-optimally if a particular individual is inadequately motivated to do his job.

However, individuals also work in groups and when the group is supposed to function as a team (and this is almost always characteristic of individuals working within man–computer information systems) group factors become pertinent. Closely allied to the formal and informal structures of a team, and dependent on these structures, is the interaction which takes place between team members, usually in the form of communication. Thus, a system may operate sub-optimally because team members perform inadequately. For example, crucial information may be transmitted too late or not at all.

The point is that many things impact on an information system's performance that are beyond the scope of the hardware and software considerations that went into the system design. Among these factors are poor human engineering of the system; individuals in the system without the aptitude to do the job; inadequately trained individuals; fatigue in key personnel; poor motivation among the operators, and poor group structure to accomplish the system's goals.

Within the present model, the impact of these external factors can be assessed by first obtaining baseline data on these elements. The effects of given external variations then may be experimentally introduced and their impact quantified. These revised performance values can then be introduced as parameters into the model and the impact these degrading factors have on total system performance can be determined. For example, the performance values for individuals at various levels of training could be introduced to determine if some optimal level of training exists which is less than that prescribed by curriculum but sufficient to insure that training beyond this level will not have a significant impact on the system.

6. Measures of Information Processing Efficiency

Typically, human factors research in the realm of information systems concerns itself with the effects of different variables operating within and/or

external to the system on the speed and accuracy of human information processing. For example, a human factors study may manipulate input load while a man retrieves data from some analogue of a storage point in the system (as in display research), or processes it (e.g., in transform studies), or inputs it (i.e., in keyboard studies). Meanwhile, the human factors researcher is measuring how long it took the man to do this and how many errors he made in the process. The results of the study then are presented to a system designer or research and development manager in the hope that these findings will be related, in some philosophic or logical way, to system performance. This integrating activity is required (although it frequently does not occur) because the measures themselves were not made in terms of impact on the system output but usually as speed and accuracy measures of the human performance alone.

Baker and Goldstein (1966) recognized the problem this *modus operandi* can create in information system display research when they observed:

> 'Common to all of these studies . . . (i.e., the display studies cited in their paper) . . . is the fact that retrieval of data from a display serves as the subject's response and terminates the task. The retrieved data are not subsequently *used* by the subject. In information system operations, on the other hand, data are generally retrieved from a display surface as inputs to other complex activities. The question is raised whether the same conclusions obtain where a display–operation task is extended to include use of the retrieved data.'

The same general question is faced by the system designer and research and development manager on a daily basis. Are the real, but small, differences presented to them from a human factors study, and the recommended changes based upon these findings, worth the cost of implementing them in a total system context? A statistically significant difference based upon millisecond variance measures may be swallowed up in the total system variance when queue length, for example, is being measured in terms of fractions of an hour. Thus, the designer and manager must concern themselves with operational or practical significance, as well as with statistically significant differences. Generally, however, there is considerable arbitrariness about what constitutes practical significance and this arbitrariness makes even more difficult the problem of relating statistical significance to practical significance.

The present model does not pretend to resolve this dilemma, but it does take the situation into account. While the classic human factors measures of human performance are incorporated in the present model, the impact on the total system is also considered. For example, operator performance measures in terms of error rate and speed in inputting data are obtained but they also can be examined with regard to their impact on efficiency of the system.

To obtain the measures necessary to test for this impact upon the system, the methodology and techniques developed by Krumm (1967) are effective tools. Basic to the measurement of information processing efficiency is the concept of the message which carries information clusters, i.e., associated data items that together yield a complete description of one aspect of an event. A configuration which expedites the transport of messages through the system is more efficient than one that does not. However, expedited message flow is of

little merit if the quality of information in the messages is degraded. Consequently, a second facet of information processing efficiency is information quality. In brief, assessment of information processing efficiency requires the measurement both of the processing of messages and of the quality of information the messages contain. Summarized in Figure 7 is a set of measures which could be used to reflect the relative 'goodness' or 'badness' of different man-computer system configurations in terms of overall system information processing efficiency.

INFORMATION PROCESSING FUNCTION	SYSTEM PERFORMANCE MEASURES		INFORMATION QUALITY MEASURES	
	THOROUGHNESS	RESPONSIVENESS	COMPLETENESS	ACCURACY
DISSEMINATION	Percentage of messages which arrive at the proper destination.	Speed of message preparation, processing, and routing.	Resistance to information losses during dissemination.	Correctness of disseminated information.
COMPUTATION		Speed with which computational reports are requested and prepared.	Completeness of computational reports.	Correctness of computational reports.
COMPILATION		Speed with which summary reports are compiled.	Completeness of compiled summary reports.	Correctness of compiled summary reports.
RETRIEVAL		Speed with which queries yield responses.	Completeness of responses to queries.	Correctness of responses to queries.

Figure 7. System measures for evaluating message processing performance and information quality. (Taken from an unpublished paper by Krumm *et al.* with the permission of the senior author).

One of the most apparent and important characteristics of an information system is the rapidity with which information is released from a source to a user. This can include the rapidity of the system in responding to a given query, or the special case where the system must compute or compile certain information. A measure of primary importance, therefore, is that of the elapsed time from the moment information is made available to the system until the message containing that information is made available to a user.

Earlier in this presentation we spoke of the system performance measure of dissemination responsiveness, but we did not label it as such at that time. You may recall that the measurement of the time required to complete the data flow throughput (depicted in Figure 3) required summing over t_k (an inserted constant for message transcription time) plus the manually measured time intervals t_1 through t_4, as well as the computer recorded time interval t_5. If we add to this the machine processing time, t_m, required to shunt the message to the appropriate user station, we have a *dissemination responsiveness measure for the system with an exact weighting of the human's contribution included.*

This of course, is a simplified case where we are concerned with a single message intended for a single user. We are also assuming that the system design specifications make explicit who should receive this particular message. Also, we are assuming that we have reliable 'machine data' to plug into our metric. Additionally, we are ignoring for the moment the quality of the message at the output end. But from this simplified illustration it can be seen that this model permits one to relate human factors measures in a rather straightforward fashion to operational measures.

We will not concern ourselves in this presentation with a detailed discussion of each of the row and column intersects in Figure 7, but one aspect, information quality measures, does warrant further mention.

When a message is received by a user, four characteristics of its content are of immediate concern: relevance, timeliness, completeness and accuracy. The first concern is that at least a portion of the information be relevant to his job. If the system provides much irrelevant information, the user may be unable to cope with the bulk of the data, and the quality of his performance is subsequently degraded. Given relevant information, he may be concerned with the timeliness of the information. In a military information system, the user wants to know the time the event under consideration occurred relative to the current time. In discussing Figure 6 it was noted that errors cannot occur in queue, but to this it should be added now that the information may be perishable. Lacking other knowledge of the situation, the user must assume that he has been provided with all the information currently available (dissemination completeness) and that the provided information is accurate.

Dissemination completeness can be defined as the percentage of data items present in a message as a function of those available and relevant. Its measurement presently requires considerable subjective judgement; thus, its general use as a measure of information quality for all messages cannot be recommended. One problem encountered when using this measure is the difficulty of determining reliably what constitutes a critical "item of information" or information element. Consider, for example, an error of omission of the type shown in Figure 6. A message that 'an enemy tank division has been sighted' may have been sent as 'an enemy division has been sighted,' with the word 'tank' omitted. Thus, the output message is incomplete but the lack of completeness is not measurable in the same sense as if the word 'division' had been dropped (yielding 'an enemy tank has been sighted'). Therefore, completeness scores for the two hypothetical messages, one of which drops 'tank' and one of which drops 'division,' cannot be considered equivalent in terms of impact on the system, even though the completeness scores may be numerically equivalent.

In talking about what constitutes an error, therefore, one can become entangled in the issue of whether the error 'makes a difference'. But some error measures, such as accuracy in the keyboard input of messages, can be objectively measured and be directly related to system performance. We earlier discussed the transformation process intrinsic in man–computer systems. We noted that it is not generally practical to program a system to 'recognise' possible but acceptable inaccuracies. Messages containing only slight inaccuracies therefore will be rejected by the computer. For example, the reader may not have noted that in each figure presented so far which depicted

the horizontal data flow dimension the word 'selection' has appeared as 'slelection'. Such an error would have been immediately sensed by the computer and if it appeared this way in a message the message would probably be rejected, thereby inflating the dissemination responsiveness measure. Thus, the primary standard of accuracy in evaluating from the system standpoint is the original message introduced into the system. The system output (whether as errors in messages at the input station or as errors in the output message which were undetected by the computer) is therefore scored in terms of data items which correspond to the input standard. Compilation and queries must be evaluated against the stored items as the standard. For output messages which contain results of computations, acceptable limits must be established to score in terms of the calculated values.

7. Concluding Remarks

I have pointed out that the developments in man machine information systems have focused on the machine involved, with little attention paid to the man. My basic thesis has been that a desirable goal in the development of an information science is the ability to predict impact on system performance from the results of studies of human information processing performance. The goal, then, is to develop a general purpose model of man computer interaction which will yield measures of system performance under different mixes of equipment, personnel, and procedures.

It was noted at the outset that this model is not a final developed simulator, but rather a base for the continued development of a measurement paradigm and predictive tool. It appears quite feasible at this time, however, to produce a real-time simulator based upon this model. The metrics and programs of Blunt (1966, 1965) can quite likely be adapted to provide a simulation vehicle for the data flow and processing dimension. The approach and programs described by Siegel and Wolf (1969) could encompass the task analysis dimension. What remains to be done is to integrate these two sets of techniques and to extend the present model to include the display and assimilate/decide functions of an information processing system. Also, more work should be directed toward refining some of the basic system criteria, e.g., the completeness measure. The end-product of these efforts would be a real-time, computer-based predictive tool for quantitatively modelling human performance in information systems.

Many benefits may be derived from the model at its present stage of development. First, it provides a cohesive structure for measuring human performance where the individual's job will be taking place in a man-machine system and where his performance will be confounded with the performance of the machine. McCoy (1963) has discussed this problem at length. It would appear, however, that the present model satisfies most of the validation goals, McCoy delineated in his theoretical paper. For example, it satisfies McCoy's goals of: (1) predicting system or element performance capability; (2) predicting user acceptance of the system or its elements; and (3) producing design information. A second value in this approach is that the data generated during the development of the task analysis dimension give an exact description of each individual's activities. This evaluation of tasks against a common standard could provide a basis for generalising results across experiments.

A good deal of information concerning communality of tasks may become available if the standardization of human factors data is undertaken along the lines suggested by Parsons and Lebach (1970).

A third benefit from this modelling approach is that it strongly links human performance implications to system performance because it is a cohesive system, based upon the flow of data through man and machine. To cite but one instance of how this model has, even at its present stage, contributed to systems hardware and software design implications, I must return to the formatting problem. About a year ago, a colleague and I examined a large number of messages that had been formatted during a particular system exercise. We found that, in the main, more than one format was required to input each of the free-text English messages (the ratio was 2·5:1 for one class of message). The system designers had been perplexed by the extremely high message traffic in the system and were running into some rather critical store and retrieve problems. The reason for their perplexity was simply this: they had assumed a one-to-one ratio of the free-text message to system format inputs. When our model input load was compared to the designer's input load, the incompatibility become evident and software/hardware efforts have since been undertaken to alleviate the problem.

A fourth benefit inherent in this approach is that it is modular and permits 'plugging' human performance studies directly into a system framework. This can be done in several different ways and along each of the dimensions described. As was just noted, human performance data can be plugged into the system data flow as parameters (i.e., the weighting factors mentioned above) and the system output examined to determine the impact. A different approach would be to 'start up' the model with randomly sampled values for the parameters for each node in the data flow and processing dimension. These values may be real, i.e., empirically derived, or theoretical. Into this flow we introduce an on-line human factors study which may have as its basic goal the development of performance measures along the task analysis dimension, but which could be providing simultaneous measures of the perturbations the human is making on system output. Later, the different task analyses values obtained may be reintroduced as parameters for 'mathematical model' configuration-optimization' runs. Another modular approach is to take measures of the impact of outside factors (i.e., the sources of variation dimension) on our task analysis performance and use these as parameters in simulation runs. For example, we can obtain logitudinal performance measures at various stages of completion of an operator training course and use these as parameters in our model for simulation runs to assess the impact on system performance of various levels of training.

A fifth benefit inherent in this modelling approach is that it provides a basis for 'cost effectiveness' determinations in laying out a human factors research programme. It is a truism in information system human factors efforts that more problems are uncovered than can ever be undertaken for solution. Which problems are the 'meaty' payoff areas? An examination of the task analysis dimension relative to the time interval nodes in the data flow and processing dimension, for example, may identify the bottlenecks in the data throughput which should be experimentally attacked. Likewise, queues give clues. But parameters can also be manipulated in simulation runs to

determine which improvements in the human portion of the system impact most on system performance. These become prime candidates for experimental examinations. The optimal parameters can also be used as the goals to be achieved in experimental attempts to improve human performance.

There are probably other values in this modelling approach, but at least one more merits comment. Even as it now stands, this model is a tested, usable tool for developing test and evaluation plans to provide human factors data during information system exercises. The approach provides an integrative coverage of all aspects and relationships of the man–machine interface and ties them to system performance measures which have been empirically verified as being usable and meaningful in an operational setting.

In closing, I have but one more thing to add. An examination of most current computer-based information systems would produce numerous acronyms and abbreviations which are used as identifiers in information systems. Those individuals who have had long experience with such systems by now must be uneasily awaiting the acronym which will be used to identify this model. I must admit there is none. For the nonce I shall simply call it MAN because the whole intent of the model has been to put the emphasis back on the man in man–machine systems.

Cet article décrit sommairement une approche pour l'élaboration d'un modèle général d'un sytème informatique dans lequel l'Homme constitue l'élément central et où l'ordinateur n'intervient qu'en tant qu'outil. L'objectif final est d'aboutir à la réalisation d'un simulateur capable de fournir des évaluations de performances obtenues avec diverses combinaisons d'équipements, de personnels et de méthodes. La base de ce modèle repose sur l'hypothèse que l'homme, dans un système informatique, a recours à cinq opérations critiques fondamentales: extraire, convertir, recueillir, assimiler de l'information et décider. Ces opérations ou domaines fonctionnels interagissent tout au long de trois dimensions: (1) la dimension du flux des données et de traitement; (2) l'analyse de la tâche pour chaque évènement dans la séquence d'émission de données; (3) la prise en compte des sources de variation, tel que le niveau d'entrainement.

Cette approche entraine plusieurs conséquences positives importantes. On retiendra surtout la possibilité offerte par le modèle de quantifier la performance au moyen de variables de systèmes, ainsi que sa valeur en tant qu'outil ayant fait ses preuves pour l'acquisition et l'évaluation de données se rapportant au facteur humain.

Diese Arbeit fasst den Versuch zusammen, ein allgemeigültiges Informationssystem-Modell zu entwickeln, dass vorwiegend Menschen betrifft und den Computer nur als ein Werkzeug benutzt. Letzte Absicht ist es, einen Simulator zu schaffen, der Messwerte der Systemleistung bei verschiedener Mischung von Ausrüstung, Personal und Verfahren liefert. Beim Aufbau des Rahmens für dieses Modell wurde angenommen, dass der Mensch fünf grundsätzliche und kritische Operationen in einem Informationssystem auszuführen hat: sichten. Übertragen, eingeben, angleichen und entscheiden. Diese Operationen oder fundamentalen Felder sind über drei Dimensionen verknüpft:

(1) einer Datenverarbeitungs- und Datenfluss-Dimension,

(2) einer aufgaben-analytischen Diversion für jedes Ereignis in der Datenfolge,

(3) einer Quelle der Variations-Diversion, wie der Übungsgrad. Das beschriebene Modell macht sich aus verschiedenen Gründen bezahlt. Ein unmittelbarer Vorteil ist die Möglichkeit, das Modell zur Quantifizierung der mesnchlichen Leistung zu benutzen; man verwendet dazu die Sytem-Masse und nimmt das Modell als getestetes, brauchbares Werkzeug, Test-und Bewertungspläne zu entwickeln und herauszubringen, welche menschliche Faktoren und Daten als Teile des Informationssystems enthalten.

References

Anon., undated, Test design for human factors in the SAGE environment. *Personnel and Training Report Prepared for Detachment 5, 26th Air Division, (SAGE).*

Baker, J. D., 1969, The uncertain student and the understanding computer. In *La Recherche en Enseignement-Programmé Tendances Actuelles*, (Edited by F. Bresson et M. Montmollin) (Paris: Dunod Press, 1969), pp. 303–317.

BAKER, J. D., MACE, D. J., and MCKENDRY, J. M., 1969, The transform operation in TOS: Assessment of the human component. *BESRL Technical Research Note* 212, *AD*697716.

BAKER, J. D., and GOLDSTEIN, I., 1966, Batch vs. sequential displays: effects on human problem solving. *Human Factors*, **3**, 225–235.

BAUER, W. F., 1963, Military command: A challenge for information processing. *Computers and Automation*, **4**, 9–15.

BLUNT, C. R., 1965, An information retrieval system model. *HRB-Singer, Inc., State College, Pa. AD* 623–590.

BLUNT, C. R., 1966, A general model for simulating information storage and retrieval systems. *HRB Singer, Inc., State College, Pa. AD* 636–435

CARBONELL, J. R., 1969, On man-computer interaction: A model and some related issues. *IEEE Transactions on Systems Science and Cybernetics*, SSC-5.

ESTRIN, G. and KLEINROCK, L., 1967, Measures, models and measurements for time-shared computer utilities. *Proceedings Association for Computing Machinery*, 85–96.

FINE, G. H., and MCISAAC, P. V., 1965, Simulation of a time-sharing system. *Professional paper presented at Institute of Management Science Meeting, San Francisco, California*, AD 611–868.

HAMILTON, W. F., and NANCE, D. K., 1969, Systems analysis of urban transportation. *Scientific American*, **221**, 19–27.

KAC, M., 1969, Some mathematical models in science. *Science*, **166**, 695–699.

KRUMM, R. L., 1967, Measurement of tactical military information flow. *Proceedings: Thirteenth Annual Human Factors Research and Development Conference, Ft. Monmouth, N. J.*, 103–114.

LYMAN, J., 1960, The methodology of task analysis: A collection of techniques. *Paper presented at the Biotechnology Seminar. UCLA.*

LIPSITZ, L., 1969, Applying systems engineering techniques to education and training. Special Issue of *Educational Technology*, June. Vol. **IX**, Nr. 6.

MCCOY, W. K., 1963, Problems of validity of measures used in investigating man–machine systems. *Human Factors*, **4**, 373–377.

MILLER, R. B., 1962, Task description and analysis. In *Psychological Principles in System Development*, (Edited by R. M. GAGNÉ) (New York: HOLT, RINEHART and WINSTON), pp. 187–227.

MILLER, R. B., 1967, Task taxonomy: science or technology? *Ergonomics*, **10**, 167–176.

NICKERSON, R. S., 1969, Man–computer interaction: A challenge for human factors research. *Ergonomics*, **12**, 501–517.

PARSONS, S. O., and LEBACH, J. L., 1970, The standardization of human factors data. *Human Factors*, **12**, 55–62.

RINGEL, S., 1966, Command Information processing systems—A human factors research program. *BESRL Technical Research Report* 1148. AD 697 716.

RINGEL, S., BAKER, J. D., STRUB, M. H., and KENSINGER, L. L., 1969, Human factors research in command information processing systems—Summary of recent studies. BESRL Technical Research Report 1158. AD 694–347.

SCHERR, A. L., 1965, An analysis of time-shared computer systems. *Ph.D. thesis, Massachusetts Institute of Technology, Cambridge, Mass.* MAC–TR–18.

SHUFORD, E. H., 1965, A computer-based system for aiding decision making. In *Information System Sciences: Proceedings of the Second Congress*, (Edited by J. SPIEGAL and D. WALKER) (Washington, D.C.: SPARTAN BOOKS, INC.), pp. 157–168.

SIEGEL, A. I., and WOLF, J. J., 1969, *Man–Machine Simulation Models* (New York: JOHN WILEY & SONS, INC.).

SPIEGEL, J., and WALKER, D. (Eds.), 1965, *Information System Sciences: Proceedings of the Second Congress* (Washington, D.C.: SPARTAN BOOKS, INC.), pp. 157–168.

TUROFF, M., 1967, Knowns and unknowns in immediate access time-shared systems. *Paper presented at the American Management Association Conference on the Computer Utility, New York.*

WARBURTON, G. B., Jr., LAWRENCE, K. A., and MARKS, M. R., 1960, SAGE Task equipment analysis: Intercept director/intercept technician. *Air Force Cambridge Research Center Technical Note AFCRC–TN–59–76.*

DISTRIBUTION

BESRL Distribution List

*1 OASD (M&RA)
1 HQDA (DACS-ZC)
*1 HQDA (DAPE-MPC)
1 HQDA (DAPE-CPS)
*1 HQDA (DAPE-DW)
2 HQDA (DARD-ARZ-B)
1 HQDA (DARD-ARB)
*1 HQDA (DARD-ARP)
*2 HQDA (DARD-OT)
1 HQDA (DARD-IST-P)
5 HQDA (DAFD-DC)
1 HQDA (DAFD-ZBD)
1 HQDA (DAFD-MF)
1 HQDA (DAFD-CN)
1 HQDA (DAMI-DCS)
5 HQDA (DAPO-PM)
1 HQDA (DAIO-ZC)
1 HQDA (DAAG-PSS-A)
1 HQDA (DAAG-ASL)
1 HQDA (DAPM-MSB)
*1 HQDA (DAPM-PL)
*1 HQDA (SGRD-MDB)
3 HQDA (EPEEC)
4 HQDA (RDSE)
1 HQDA (RDRE)
1 HQDA (RDRD)
*1 HQ USAMC, ATTN: AMCRD-TE
2 HQ USCONARC, ATTN: GI-ATPER
10 HQ USCONARC, ATTN: ATIT-STM
2 HQ First US Army
2 HQ Third US Army
2 HQ Fifth US Army
2 HQ Sixth US Army
1 HQ Sixth US Army, ATTN: Library
*6 HQ USACDC, ATTN: DCS/Opns QAD
1 HQ USACDC, ATTN: Library
1 HQ USASA, ATTN: IARD-T
*1 HQ USA Computer Sys Cmd, ATTN: CSCS-TMT-SD
*1 HQ USA Recruiting Cmd, ATTN: USARCO
1 Dir, Project MASSTER, Ft Hood
*1 USA Electronics Cmd, ATTN: AMSEL-CT-A
*1 USA Electronics Cmd, ATTN: AMSEL-CB-AS
*1 USA Electronics Cmd, ATTN: AMSEL-PA-AH
1 USACDC Exper Cmd, Ft Ord, ATTN: Plans Officer
*1 USACDC Exper Cmd, Ft Ord, ATTN: Library
*1 USACDC, Cbt Sys Gp, ATTN: CSYGC-S
*1 USACDC Institute of Land Combat, ATTN: Library
1 USACDC Armor Agency
1 USACDC Artillery Agency
1 USACDC Aviation Agency
1 USACDC Infantry Agency, ATTN: CAGIN-OA
1 USACDC Infantry Agency, ATTN: Central Files
1 USACDC SW Agency
1 USACDC Pers & Adm Svcs Agency
*1 USACDC Liaison Ofc, USAF, Tact Air Warfare Cen, Eglin AFB
1 USA Adv Mat Concepts Agency, ATTN: AMXAM-TS
1 WRAIR, ATTN: Neuropsychiatry Div.
*1 WRAIR, ATTN: Dept of Exper Psycho-physiology
*1 USA Med Res Lab, Ft Knox, ATTN: Exper Psychol
*1 USA Natick Labs, ATTN: Library
1 USA Natick Labs, ATTN: Psychol Labs
1 USA Natick Labs, ATTN: Assoc Dir, Beh Sci, Pion Div
*1 USA Mobility Eq. R&D Cen, ATTN: HFE
*1 USA Mobility Eq. R&D Cen, ATTN: Library
*1 USA Electronic Prvg Grd, ATTN: STEEP-SU-I
*1 USA Electronic Prvg Grd, ATTN: STEEP-T-BI
2 USA Aberdeen Prvg Grd, ATTN: Dir, HEL
*1 USA Aberdeen Prvg Grd, ATTN: HEL, R. A. Monty
*1 USA Edgewood Arsenal, ATTN: Hum Factors Gp, Biomed Lab
1 USA Tropic Test Cen, Ft Clayton, ATTN: STETC-PD-M
2 USA Arctic Test Cen, Alaska
*1 USA Gen Eq. Test Activ., Ft Lee, ATTN: HF Div, MED
*1 USA Avn Mat Lab, ATTN: Library
*1 EWL, Ft Holabird, ATTN: Intel Mat. Dev. Off.
*2 USA Garrison, Ft Huachuca, ATTN: Tech Ref Off
1 USA C&GSC, ATTN: Educ Adv
6 USA C&GSC, ATTN: Library
1 USA C&GSC, ATTN: Beh Sci Rep, Dir Grad Stud & Res
1 USA C&GSC, ATTN: DOI
*2 USMA, Mil Psych & Ldrshp
*1 USMA, Dir of Institutional Res
1 USMA, Library
1 USA Ordn Cen & Sch, Aberdeen PG, ATTN: DOI
1 USA Ordn Cen & Sch, Aberdeen PG, ATTN: ATSOR-1R
2 USA Engr Sch, Ft Belvoir, ATTN: DOI
*2 USA Mgt Sch, Ft Belvoir
1 USA Inf Sch, Ft Benning, ATTN: DOI
*1 USA Inf Sch, Ft Benning, ATTN: AJIGP
*1 USA Inf Sch, Ft Benning, ATTN: AJIIS-H
1 USA Inf Sch, Ft Benning, ATTN: Library
1 USA Inf Bd, Ft Benning, ATTN: Secy ATBD
1 USA Air Def Sch, Ft Bliss, ATTN: DOI
*2 USA Air Def Sch, Ft Bliss, ATTN: Library
1 USA Air Def Sch, Ft Bliss, ATTN: ATSAD-DL-C
*1 USA Air Def Bd, Ft Bliss
1 USA Inst Mil Asst, Ft Bragg, ATTN: DOI
1 USA Inst Mil Asst, Ft Bragg, ATTN: ATSMA-ID
1 USASA Tng Cen & Sch, Ft Devens
2 USA Transport Sch, Ft Eustis, ATTN: DOI
2 USA MP Sch, Ft Gordon, ATTN: DOI

*Does not receive reports for all research areas.

1 USA SE Sig Sch, Ft Gordon, ATTN: DOI
1 USA SE Sig Sch, Ft Gordon, ATTN: Ed Advsr
2 USA Chaplains Sch, Ft Hamilton, ATTN: DOI
2 USA AG Sch, Ft Benjamin Harrison, ATTN: DOI
2 USA Fin Corps Sch, Ft Benjamin Harrison, ATTN: DOI
*1 USA Med Fld Svc Sch, Ft Sam Houston, ATTN: Stimson Library
2 USA Cbt Survl Sch Tng Cen, Ft Huachuca, ATTN: DOI
2 USA Int Cen & Sch, Ft Huachuca, ATTN: DOI
*1 USA Int Cen & Sch, Ft Huachuca, ATTN: AHBH S-CB-(ASRC)
*1 USA Int Cen & Sch, Ft Huachuca, ATTN: Library
1 USA Armor Sch, Ft Knox, ATTN: DOI
*1 USA Armor Sch, Ft Knox, ATTN: AHBAAS-DMP
2 USA QM Sch, Ft Lee
2 USA Chem Corps Sch, Ft McClellan
2 USWAC Sch, Ft McClellan, ATTN: DOI
1 USA Sig Cen & Sch, Ft Monmouth, ATTN: DOI
1 USA Sig Cen & Sch, Ft Monmouth, ATTN: Educ Advsr
1 USA Msl & Mun Cen & Sch, Redstone Arsnl, ATTN: DOI
*1 USA Msl & Mun Cen & Sch, Redstone Arsnl, ATTN: Lib
2 USA Avn Sch, Ft Rucker, ATTN: DOI
1 USA Avn Sch, Ft Rucker, ATTN: Library
*1 USA Avn Test Bd, Ft Rucker, ATTN: STEBG-TP-V
*1 USA Fld Arty Sch, Ft Sill, ATTN: DOI (Ed Svcs Div)
2 USA Prim Hel CenSch, Ft Wolters, ATTN: DOI
2 ONR, Code 458
3 US Navy, BuPers (Pers A3)
*1 US Navy, BuM&S, Code 513
*1 US Navy, BuM&S, Code 713
1 Nav Pers Tng Rsch Lab, San Diego, ATTN: Library
1 Nav Pers Tng Rsch Lab, San Diego, ATTN: Stat Dept
*3 Nav Pers Tng Rsch Lab, San Diego, ATTN: Pers Meas Rsch Dept
2 Nav Pers R&D Lab, Washington
*1 Nav Med NA Rsch Unit, San Diego
15 Nav Rsch Lab, Library, Code 2029
1 Nav Rsch Lab, Code 2027
*1 Nav Tng Dev Cen, Orlando, Code 55
*1 Nav Aerospace Med Inst, Pensacola, Code 31
1 Nav Postgraduate Sch, Monterey, ATTN: Library
*2 HQ USMC, ATTN: ADIB
*1 HQ USAF (AF/DPXYA)
*1 HQ USAF (INYMA)
1 HQ AFSC/DLSL
*1 HQ AFLS DPCB
*1 SMAMA(DPCB)
1 USAF Air University AUL/LSA
3 USAF School of Aerospace Med-Aeromedical Lib (SCL-4)
3 US Air Force Academy, PDO 4013A
*1 US Air Force Academy, DMPL
1 AFHRL (DOJZ), Brooks AFB
*1 AFHRL (FT), Williams AFB
1 AFHRL/MD, Alexandria, Va.
*3 AFHRL (PD), Lackland AFB
*1 CINCPACAF (IGSAG)
2 US Armed Forces Institute
*1 American Embassy NATO International Staff
*1 US Dept of Agriculture, Pers Rsch Staff
*1 US Dept of Labor, Info Cen for Mpr Rsch
2 US Coast Guard Hq, C/Psychol Rsch
*1 US Coast Guard Acad., Director of Admissions
*1 US Coast Guard Tng Cen., Governors Island, Educ Advis.
*1 National Security Agency, ATTN: M13
*1 Central Intelligence Agency, ATTN: OCR/ADD/Publications
*1 Nat Cen for Child Health and Human Dev
1 NIMH OC NCMHI
*1 FASEB, Life Sciences Rsch Ofc
*1 BLM, Denver
2 HumRRO, Alex., ATTN Library
2 HumRRO Div 2, Ft Knox
1 HumRRO Div 3, Presidio of Monterey
1 HumRRO Div 4, Ft Benning
*1 HumRRO Div 5, Ft Bliss
1 HumRRO Div 6, Ft Rucker
1 Inst. for Def Anal., Arlington
1 Rsch Anal Corp, McLean, ATTN: Library
1 RAND Corp, Santa Monica, ATTN: Library 98D
*1 Cen for Nav Anal, Arlington, ATTN: Document Center
*1 AIR CRESS, Kensington, ATTN: Info Sys Br
1 Hum Engr Info & Anal Svc, Tufts Univ
*1 Biological Abstracts
1 Univ Illinois, Aviation Rsch Lab
*1 Human Factors Rsch Inc, Goleta
1 Litton Sci Sup Lab, Ft Ord, Behavioral Sciences
140 Library of Congress, Unit Doc Exped Proj
6 Library of Congress, Exchange & Gift Div
12 Defense Documentation Center
*4 Dir Psych, Army Hq, Russell Ofcs, Canberra
1 Scientific Advsr, Mil Bd, Army Hq, Russell Ofcs, Canberra
1 Mil and Air Attache, Austrian Embassy
*1 Centre de Recherche Des Facteurs, Humaine de la Defense Nationale, Brussels
4 British Defense Staffs Washington, ATTN: Scientific Officer
2 Canadian Joint Staff Washington
3 C/Canadian Defense Rsch Staff, C/CRDS(W)
1 C/Air Staff, Royal Canadian AF, ATTN: Pers Std Anal Br
*1 Def & Civ Inst of Environ Med, Canada
*1 Militaerpsykologisk Tjeneste, Copenhagen
*1 Military Attache, French Embassy, ATTN: Doc Sec
*1 Medecin Chef, C.E.R.P.A.-Arsenal, Toulon/Naval France
1 Prin Scientific Off, Appl Hum Engr Rsch Div, Ministry of Defense, New Delhi
1 Pers Rsch Ofc Library, AKA Irgun, Israel Defense Forces
*1 Ministerie van Defensie, Oper Officer Personeel KL, Afd Sociaal Psychologische Zaken, The Hague, Netherlands

*Does not receive reports for all research areas.

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Behavior and Systems Research Laboratory, Arlington, VA.	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

Quantitative Modeling of Human Performance in Information Systems

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

James D. Baker

6. REPORT DATE June 1972	7a. TOTAL NO. OF PAGES 30	7b. NO. OF REFS 28
8a. CONTRACT OR GRANT NO. b. PROJECT NO. DA R&D Proj No. 2Q062106A723 c. Command Systems d. a-11	9a. ORIGINATOR'S REPORT NUMBER(S) Technical Research Note 232 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY USA Combat Developments Command, Ft Belvoir, VA.

13. ABSTRACT

This publication[1] summarizes an approach toward developing a general information system model which focuses on man and considers the computer only as a tool. The ultimate objective is to produce a simulator which will yield measures of system performance under different mixes of equipment, personnel, and procedures. The model is structured around three basic dimensions: 1) data flow and processing, 2) task analysis, and 3) outside sources of variation in the system. Five basic and critical functional areas represented in the model are screening incoming messages, transforming messages to computer format, inputting messages, assimilating data displayed, and deciding on courses of action based on information obtained. The impact of human performance in the model is reflected in measures of system performance (thoroughness of information and responsiveness to the user need) and quality of information (completeness and accuracy.

The model at present stage is a tested implement for human factors experimentation on the Army's information processing systems. The approach provides integrative coverage of all aspects and relationships of the man-machine interface and ties them to accepted system performance measures.

[1] Contents of this publication were presented in a paper at the Fourth International Congress on Ergonomics, Strasbourg, France, 6 thru 10 July 1970 as the opening address of the Machine-Aided Processing of Information Session. The text given here is as reprinted in ERGONOMICS, 1970, Vol 13, No. 6, 645-664.

DD FORM 1 NOV 68 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Unclassified
Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
*Information systems						
Decision making						
Automated systems						
Command information processing systems						
*Quantitative model						
*Performance measurement						
*Performance prediction						
*Man-Computer interaction						
*Mixes						
Personnel						
*Conceptual model development						
System performance						
Equipment						
Procedures						
System evaluation techniques						
Methodologies, system evaluation						